CF-3 Paleontology

FAX

DATE: April 10, 1998

TO: Perry Charley, Navajo AML Project Manager

FROM: Grace Irby, MNA Paleo Contract Coordinator

RE: Cameron 3 Final Paleo Report, Contract C97293

Four copies of the above report were sent to you yesterday via UPS & should reach you on Monday, April 13, 1998. Two copies have color prints of the significant fossils recovered and two have color copies of the prints, in accordance with the requirements stated in Exhibit C, Page 1, Statement of Work, in our above contract.

The location maps are included in this report. All co-authors have been advised that this report is the property of the Navajo Nation and no part of it can be reproduced or made available to the general public without the written consent of the Navajo Nation.

I called your office yesterday morning to determine where all the report copies should be sent. Since you were out-of-town, Carl Holiday told me that all copies should be sent to you, and that your office would distribute them to the Minerals Department. I wanted to be sure that it was not my responsibility to send one to the Minerals Department because they are noted in Exhibit B, page 2 of our above contract.

Again, thank you for the opportunity to do this paleo work for you. It has been our pleasure to work with the Navajo Nation in preserving for posterity the paleontological treasures on your land.

TO: Mr. Perry Charley
FROM: Grace Irby, NAMLRD

DRAFT COPY,
no illustrations -
3/31/98
Grace Irby
520-825-1394
please refer to today's
FAX memo
for comments

RESULTS OF PALEONTOLOGIC SALVAGE AND MONITORING OF CAMERON 3 PROJECT, NAVAJO ABANDONED MINE LAND RECLAMATION DEPARTMENT, TUBA CITY, ARIZONA

Larry Coats

Grace Irby

Mary Carpenter

Caroline Orell

INTRODUCTION

The Navajo Abandoned Mine Land Reclamation Department (NAMLRD) at Tuba City, Arizona, reclaimed eleven open pit uranium mine sites (Table 1), near Cameron, Arizona, under the Cameron 3 Project, beginning in June of 1997 and ending January, 1998. This operation was required and funded by the United States Office of Surface Mining (U.S. Department of the Interior).

TABLE 1. Cameron 3 Sites

NA-0155a	NA-0155b	NA-0163	NA-0166
NA-0172a	NA-0172b	NA-0173	NA-0174
NA-0175	NA-0179	NA-0180	

Talked w/ Orbin
@ 2:00 pm
4/8/98 re comments.

Prior to the reclamation, the NAMLRD contracted the Museum of Northern Arizona (MNA) to conduct a field investigation of these sites, including the open pits and surrounding waste piles, to determine if paleontological resources might be encountered during the reclamation activities because the sites are located in the fossiliferous Chinle Formation. The MNA Cameron 3 Field Survey Report by Kirby et al. (1992) determined that six of the above sites, NA-0155a, NA-0166, NA-0172a, NA-0172b, NA-0173, and NA-0175, would require paleontological salvaging and monitoring. The locations of these six mine sites are noted on the map in Figure 1.

This report contains the results of the paleontologic salvage and monitoring procedures that were conducted before and during the reclamation operations. The fossil identification and significance is discussed in the Background and Paleoenvironmental Setting and Systematic Paleontology sections, and for each mine site individually. A copy of the original MNA Navajo Nation Minerals Department Salvaging and Monitoring Permit is included in Appendix 1.

BACKGROUND

The Petrified Forest Member of the Chinle Formation, in which the majority of the fossils were recovered during this project, has been well-known for the past century for its abundance of vertebrate paleontological specimens. Paleontological investigations began in 1899, under the leadership of Dr. Lester Ward, but the most detailed and systematic study of the vertebrate fauna of the Chinle Formation was undertaken by Charles L. Camp, beginning in 1921 (Long and Murry, 1995). During the next thirteen years, Camp and his associates were able to recover and identify dozens of large and small specimens of a diverse amphibian, reptile, and piscine (fish) fauna, many species of

which had never been previously described. Much of Camp's descriptive work remains definitive to the present. Among the vertebrates described by Camp were lungfish of the genus *Ceratodus*, large stereospondyl amphibians, *Metoposaurus*, and thecodont reptiles of the genus *Rutiodon*, more commonly known as phytosaurs (Colbert, 1985).

Paleontological study of the Chinle Formation has continued sporadically to present, and many of the recovered specimens are currently curated at the Museum of Northern Arizona, which proved useful in this study for use as comparative material.

Critical to a detailed understanding of the vertebrate fauna of the Chinle Formation, and especially to the environmental and ecological setting in which these animals lived, is the correlation of the numerous depositional episodes, in order to account for the chronology of events, and to establish synchrony or asynchrony of the various species that lived in Arizona during the late Triassic (approximately 230 to 208 million years before present). Unfortunately, this has proven impossible for the Chinle Formation. Due to the discontinuous nature of the prominent sandstone marker beds in the Chinle Formation, stratigraphic correlation of these depositional episodes cannot be accomplished even within the confines of the Petrified Forest National Park (Billingsley, 1985), much less between more far-flung fossil localities, such as the Cameron 3 reclamation project. Although prominent sandstone marker beds were present in all sites, correlation of these beds with other fossil localities in northern Arizona has thus far proven impossible (Kirby et al., 1992). Detailed laboratory analysis of sedimentary structures observed at the Cameron 3 sites was not attempted for this salvage project. For a more detailed examination of the stratigraphic positions of the mine sites within the Chinle Formation, see Kirby et al. (1992).

PALEOENVIRONMENTAL SETTING AND SYSTEMATIC PALEONTOLOGY

North America of the Late Triassic was vastly different than the continent we live on today, and, accordingly the landscape in which the Chinle Formation was created, varied dramatically from the arid Colorado Desert conditions at the Cameron 3 site at present. Located on the northeastern edge of Pangaea, (the Triassic super-continent), what was then northern Arizona was near the equator, and lying only a short distance from the western ocean (Figure 2). The Chinle was formed on a low-relief coastal plain, being fed sediments from the volcanically active southern region, which also periodically deluged the study area with volcanic ash and lahars, (mud flows composed of loose volcanic materials). Paleochannels, or the pathways of ancient rivers and streams in the region drained to the northwest, following meandering courses to the Triassic Sea (Kirby et al., 1992; Smiley, 1985). Examination of a large paleochannel in site NA-0175 by monitor Randy Reed agreed well with this scenario, and documented gradual channel migration from east to west.

The climate of the study area during the Triassic has no modern analog, due the massive differences in global circulation patterns then as compared to now (Smiley, 1985), but the flora and fauna of the region were consistent with an equatorial, intermittently flooded coastal plain, containing numerous shallow lakes, marshes, and swamps. The large trees, gymnosperms of the species *Araucarioxylon*, *Woodworthia*, and *Schilderia*, that were the source for the well-known petrified "forests" we see today, probably did not live in this region but were transported there by volcanic ash-flow episodes or floods, as

evidenced by the stripped down nature of most of the fossilized trunks (Colbert and Johnson, 1985).

Within this swampy lowland, members of the amphibian and reptile families were quite successful at carving out ecological niches, and numerous genera persisted for millions of years. Notable among these primitive species were Labyrinthodont amphibians known as metoposaurs. These heavily armored "shovel-headed" amphibians are well-known from the Painted Forest member of the Chinle Formation, especially the species tentatively identified from specimens recovered during this study, *Buettneria perfecta* (Figure 3). Presumably, these creatures were aquatic predators that lived in large numbers in shallow lakes that occasionally desiccated, as evidenced by frequent discoveries of multiple individuals that have been found in apparent lake sediments (Carroll, 1988). Definitive identification of *B. perfecta* is only possible if complete, or almost complete, craniums are recovered, as diagnosis relies upon specific characters of the orbit of the eye (Long and Murry, 1995). Fragmentary cranial and postcranial elements recovered from Cameron 3 clearly distinguish Metoposauridae, and the only robust species thus far identified in the southwestern United States is *B. perfecta* (Long and Murry, 1995; Spencer Lucas, pers. comm., 1998). However, a smaller, less well-known metoposaur, *Apachesaurus gregorii*, was also identified from materials salvaged from NA-175, and was diagnosed on the basis of a vertebral centrum that is much more elongate than *B. perfecta*.

Equally common in this paleoenvironment of the late Triassic were primitive thecodont reptiles known as phytosaurs. These creatures resembled modern crocodiles in morphology (Figure 4), and were effective carnivores, as evidenced from the variety of

other reptiles documented from stomach contents of a specimen from India (Chatterjee, 1978). A phytosaur distal tibia fragment recovered from NA-175 (Area L) displays a prominent bite-mark which matches well with phytosaur dentition (Figure 4), adding evidence that these carnivores were unselective in their predatory behavior. Extreme heterodonty, or differentiation of the teeth from various positions within the mouth, demonstrates the evolutionary specialization that this genera had undergone to achieve a successful dental pattern, but this also makes identification of species problematic as a single individual may have a dozen or more tooth morphologies. All teeth recovered from this project, with the single exception of a tiny tooth attributed to *B. perfecta*, were generically assigned to Phytosauridae.

A notable exception to the ubiquity of carnivores in the paleontological materials recovered from Cameron 3, which is presumably typical of this paleoenvironmental setting at large, is the heavily-armored aetosaur, *Desmatosuchus haplocerus* (Figure 5). Dentition from other specimens are indicative of a herbivorous diet, displaying small leaf-shaped teeth, with tooth loss and modification of the premaxilla into a specialized form adapted for cropping vegetation (Carroll, 1988), very similar to the specialization of the anterior dentition found in modern artiodactyls, such as cervids or bovids (deer, elk, bison, cattle, etc.).

Mostly poorly understood of all the species identified from this study is the formidable Triassic predator, *Postosuchus sp.* (Figure 6). These advanced members of the family Rauisuchia were medium to large in size (up to 7 m in length), and possessed specialized predatory dentition, with recurved, dagger-like teeth (Long and Murry, 1995). Further evidence of their dominance over other carnivores of the period is the lightness of their

dermal armor, in contrast to all other species discussed thus far. Dangerous enemies to such a creature must have been few and far between. Classification of rauisuchians has proven problematic, with much confusion over the relationships within the group. One author has suggested that *Postosuchus* might be closely related to tyrannosaurid dinosaurs of the Cretaceous (Chatterjee, 1985), based upon modifications in the articulation between the pelvis and femurs that indicate evolution towards a more erect, possibly bipedal, posture (Carroll, 1985; Long and Murry, 1995). However, the only trackways found from members of this family have thus far proven quadrupedal (Long and Murry, 1995). Most workers provisionally classify the rauisuchians as paraphyletic (Long and Murry, 1995), and find the rear limb specialization as structured in a manner opposite of the pattern of dinosaurian orders (Carroll, 1985). The only species of the genus *Postosuchus* thus far diagnosed is *P. kirkpatricki* (Chatterjee, 1985; Long and Murry, 1995), but so little identifiable material was recovered during this project to make diagnosis beyond genus speculative.

METHODOLOGY

The methodology used for the Cameron 3 Project was similar to what was described by Kirby et al. (1992) for the Cameron 1 Project. The only in situ specimens recovered in the course of this project were from site 155a, and required stabilization, plaster casting, and removal from sandy bentonitic matrix.

Monitoring of the uranium pits, pit walls, and flanking radioactive waste piles during reclamation operations involved following the bulldozers and scrapers, and observing the freshly scraped ground surfaces for newly uncovered fossils.

Since the majority of specimens were recovered as float from the surface of waste piles, pit walls, and pit rims, discussion of the behavior of bentonitic sandstone is required. Derived from Triassic volcanic ash falls and lahar flows, bentonite is formed from the breakdown of these materials into a montmorillonitic clay that comprises the bluish-gray stratified layers so prevalent in the salvage area, and throughout the Painted Desert (Smiley, 1985). This material is ideal for the preservation of fossil remains, but complicates the work of modern day paleontologists. The surface of this clay, to a depth exceeding 15 cm, easily absorbs water from precipitation and swells or shrinks according to moisture content. This behavior often brings paleontological materials to the surface as "float," but also usually obscures stratigraphic relationships. Central to this discussion is the fact that precipitation will result in the exposure of more fossil material on the surface. The survey portion of this study was conducted during April of 1992, after an exceptionally wet late winter and early spring. Thus large numbers of fossils were revealed on the surface, and the survey team made optimistic predictions about the results of salvage operations. However, when the salvage work took place, during late summer, fall, and winter of 1997/98, the study area was experiencing an exceptionally dry period, with only minor precipitation occurring throughout the reclamation operation, so very little additional fossil material surfaced. As no large quantities of bone, or indeed any bone-rich fossiliferous layers as noted by the survey team, were located by the salvage team, it is suggested that the vagaries of weather are of central importance to recovery efforts of this type. It is further suggested that these sites, especially the more productive sub-sites, be resurveyed periodically, especially after heavy precipitation episodes.

PALEONTOLOGIC SALVAGE AND MONITORING

Site NA-0155 (Charles Huskon No. 10) MNA Loc. 1391

This site is divided into two separate subsites, 155a and 155b (Figure 7). 155b was excluded from salvage and monitoring due to lack of significant fossil finds during, and excessively high radiation readings.

Survey. - Preliminary survey of both sites was done by MNA in 1992. Paleontologic samples collected from subsite 155a occurred as float, from in-situ specimens in undisturbed outcrops, and from litter on the surface of waste piles. Two in-situ vertebrate specimens occurred at the east end of the pit, in a fossiliferous horizon 1.5 to 2 m above the ore-bearing sandstone. A third in-situ specimen was found in a second horizon 7 to 7.5 m above the first, at the western end of the pit. Subsurface bone concentrations were left in place for subsequent salvage (Kirby et al., 1992). Specimens collected were assigned MNA collection numbers and are housed at MNA.

Salvage. 155a - Reconnaissance of the site on June 18 and 19, 1997 by Mary Carpenter, Phil Gensler, and Carl Holiday revealed no new fossils eroding from waste piles or in-situ sediments. Bone fragments were collected eroding from reddish-brown, bentonitic clays near the top of an in-situ hillside at the west end, north flank, of the pit. These bone fragments were collected from the same site as the above mentioned "third in-situ specimen" found during the 1992 survey (Kirby et al., 1992). The previously collected specimens from "a" are now designated as MNA #V1391-4.

Monitoring. 155a - Monitoring by Mary Carpenter took place from July 8 through August 8, 1997. Significant fossils were found in-situ in the Chinle hillsides near the east

entrance of the pit on both the north and south flanks. One specimen not in-situ was found eroding downslope at the extreme east end, south flank. Numerous plant impressions and carbonized plant materials were found in-situ in the bulldozed side of a hill along the north flank. No fossils were found in waste piles with the exception of a few small fragments of carbonized wood in waste already moved into the bottom of the pit, west end.

All in-situ vertebrate fossils were collected from medium to dark brown and reddish-brown bentonitic clays grading stratigraphically downward into a hard siltstone or fine-grained sandstone, medium reddish-brown in color. Specimens (field numbers) 155a-02 and 155a-03 were excavated from bentonitic material, with the base of the bones resting either on top of the hard siltstone, or up to a few centimeters into the siltstone layer.

Results. This site yielded several in situ bone specimens, still embedded within sedimentary (unnamed sandstone unit) beds, and included the following elements of phytosaurs:

Reptilia (Archosauria)

Parasuchia

Phytosauridae

Subsite 02

1 almost complete interclavicle (unusual specimen, rare)

1 almost complete rib

1 almost complete fibula

1 fragmentary scapula

1 fragmentary femur

2 teeth, and many fragments

Subsite 03

1 large rostral specimen (snout) and many fragments

Site NA-0166 (Yazzie No. 105)

Site NA-0166 (Figure 10) is interpreted as being within the informal sandstone and mudstone member of the Chinle Formation which is directly overlain by the Petrified Forest Member. Sandstone blocks in the waste piles ranged in color from tan to yellowish-brown to gray.

Survey. - Preliminary survey of this site was done by MNA in 1992. Fossil occurrences at 166 are dominated by large sandstone blocks in the waste piles on the northwestern and southeastern perimeter of the pit, and by moderately large-sized fragments of petrified logs in the piles and pit. The sandstone blocks bear large impressions of leaf, woody stem, and bark fragments, and the largest of the impressions is an elongate, strap-like leaf structure (Kirby et al., 1992), 78 inches in length an 7 inches wide, with a ridged or segment-like texture. Dr. Sidney R. Ash, paleobotanist at Weber State University in Ogden, Utah considered similar specimens at site NA-0125 comparable to foliage of the cordaitean plant Pelourdea (Kirby et al., 1992).

Salvage. Salvage activities by Mary Carpenter, Phil Gensler, and Carl Holiday, took place on June 18, 1997. Photographs were taken of plant impressions in sandstone blocks too large for recovery in Waste Piles 1 and 2 on the southeast flank of the pit. Burrow casts occurred in a waste pile on the northwest flank and were photographed, but not collected. A large specimen fossilized wood was collected from the southeast waste

pile area. All impressions occurred in a medium- to coarse-grained, tan to yellowish colored sandstone.

Monitoring. Monitoring of site NA- 0166 was not conducted, following the recommendation of the preliminary survey team (Kirby et al., 1992)

Results. Only one specimen was collected, a large fossilized log, collected by Carl Holiday:

Plantae

cf. *Araucarioxylon sp.*

1 large (X cm x X cm) specimen of petrified wood (measure coming)

MR. PALEO HIMSELF. Wonder how HP fits in w/these duties?

Site NA-0172a and Site NA-0172b (RAMCO No. 21)

Survey. Preliminary survey of these adjacent sites, 172a and 172b (Figures 11 and 12) was conducted by MNA in 1992. No in situ fossil localities were noted, and only a few specimens were collected as float (Kirby et al., 1992).

Monitoring. Reclamation activity conducted at these two sites was monitored by Mary Carpenter, Larry Coats, and Caroline Orell from October 1 through 15, 1997.

Results. No paleontological specimens were recovered during reclamation of these two sites.

Site NA-0173 (RAMCO No. 22)

Survey. Preliminary survey by MNA in 1992 revealed a "diverse and abundant paleontological sample" present at site 173 (Figure 13), represented by metoposaur bone fragments, phytosaur teeth and bone fragments, aetosaur scutes, and tetrapod coprolites

(Kirby et al., 1992). Several in situ concentrations were noted, and recovered materials were collected from slump scars on gravel-draped slopes abutting the northeastern pit rim and northernmost adit (Kirby et al., 1992).

Salvage. No in situ specimens were found.

Monitoring. Reclamation operations at NA-0173 were monitored by Caroline Orell and Larry Coats from October 15 through 31, 1997. Monitoring at site focused on the 2 large waste piles that were removed to back-fill the pit, the pit walls, and the gravel-draped outcrop slopes that border the site to the north. Two localities (Subsites G and Y, as noted on Figure 13) were especially productive, and yielded numerous faunal specimens. However, all specimens recovered were revealed as surficial float, no in-situ concentrations were located, although some areas yielded numerous specimens. No in situ concentrations were found on the surrounding gravel-covered terraces either, or in the amphitheater formed by small drainages along the northwestern perimeter of the site, as discussed by Kirby et al. (1992).

Results. An extensive collection of fossils were collected from site NA-0173, including abundant vertebrate bones, teeth, and dermal armor fragments. Notable among them were several specimens identifiable as *Desmatosuchus haplocerus*, a very large(4 to 5 m in length), herbivorous aetosaurian considered indicative of a Late Carnian/ Early Norian age (Long and Ballew, 1985; Kirby et al, 1993). A detailed list of specimens follows:

Area G

Amphibia (Metoposauridae)

cf. *Buettneria perfecta*

14 skull fragments

7 interclavicle/ shoulder girdle fragments

1 palatal fragment (juvenile)

Reptilia (Aetosauria)

Desmatosuchus haplocerus

3 dermal armor fragments

Area Y

Amphibia (Metoposauridae)

cf. *Buettneria perfecta*

7 skull fragments

Reptilia (Archosauria)

Parasuchia

Phytosauridae

5 centra (vertebral) fragments

3 rib fragments (one partially reconstructed)

22 skull fragments

Site NA-0175 (Ryan No. 2)

Survey. The 1992 survey of site NA-0175 (Figure 18) also yielded a diverse paleontological sample, dominated by well-preserved coprolites (Kirby et al., 1992). The majority of these specimens were collected as float from the large, north-central waste piles. No in situ deposits were noted.

Monitoring. Because of the areal extent and rugged character of this site, the largest by far of any investigated in the course of this project, monitors were paired for the initial stages of monitoring operations. Monitoring was conducted by Caroline Orell, Larry Coats, Randy Reed, Nellie Lavin, and Blaine Schubert, during the course of reclamation that took place from October 31, 1997 until February 5, 1998. Initial focus was upon the waste piles, which lined the site on its northern perimeter. As noted by Kirby et al. (1992), numerous coprolite specimens were collected, as well as isolated bone fragments. As monitoring activities shifted to the pit rims, numerous specimens were recovered as float from pit walls, rims, and small natural hills surrounding the site. Especially productive were subsites H and L (noted on Figure 18). As monitoring activities progressed into the middle of winter, specimens were noted to emerge from the benthonitic clay matrix, apparently by action of repeated freezing and thawing. Subsite L was discovered by examining the nearest natural hills adjacent to the site, just northeast of Waste Pile 1.

Results. The collection of materials from site NA-0175 is comprised of well-preserved coprolites, fragmentary vertebrate elements, including bone, teeth, and dermal armor. Notable among them is a fragmentary phytosaur distal tibia displaying a prominent bite-mark which matches well with phytosaur dentition. Following is a detailed listing of specimens:

Tetrapoda

Many coprolites, some pyritized

Amphibia (Metoposauridae)

cf. *Buettneria perfecta*

1 interclavicle fragment

1 tooth

Amphibia (Metoposauridae)

Apachesaurus gregorii

1 centrum (vertebral portion)

Reptilia (Archosauria)

Parasuchia

Phytosauridae

39 teeth and tooth fragments

1 scute (dermal armor)

1 dentary (lower jaw) fragment

Reptilia (Aetosauria)

Desmatosuchus haplocerus

1 lateral cervical spine fragment

1 dermal armor fragment

Reptilia (Rauisucha)

Rauisuchidae

Postosuchus sp.

2 skull fragments

1 centrum (vertebral portion) fragment

Area L

Reptilia (Aetosauria)

Desmatosuchus haplocerus

1 spine fragment

22 dermal armor fragments

Reptilia (Archosauria)

Parasuchia

Phytosauridae

34 mid-dorsal osteoderm fragments

1 distal tibia fragment with (Phytosaurian?) bite mark

1 scute fragment

1 dentary fragment with embedded tooth

SUMMARY OF RESULTS

Paleontologic salvage and monitoring of Cameron 3 Project has produced a small but significant collection of fossil specimens. The fossils represent plant and vertebrate material taxonomically and biostratigraphically important, as well as including species only rarely recorded from the Chinle Formation. The Museum of Northern Arizona holds these specimens in trust for the Navajo Nation.

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